POST-MORTEM DIAGNOSIC FOR THE TAIWAN LIGHT SOURCE

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Abstract

Analyzing the causes of various trip events is helpful to improve reliability of a synchrotron light source. To identify the causes of trips at Taiwan Light Source (TLS), various diagnostics tools were employed. These diagnostic tools can capture beam trips, interlock signals of superconducting RF system, waveforms of the injection kickers, quench and interlock signals of the superconducting insertion device, and instability signals of the stored beam for post-mortem analysis. These diagnostic systems can routinely monitor signals and record beam trip events. Features of trip diagnostic tools are available now. System configuration and experiences will be summarized in this report.

INTRODUCTION

The beam trip event diagnostic is important for the TLS to improve operation reliability. A complete beam trip diagnostics can clearly reveal and track causes of the beam trip and provide enough information for maintenance. Currently available diagnostic tools include data archivers of the control system with 100 msec resolution, a 16-channel 16 bits data recorder with 10 μsec resolution, a 96-channel simultaneous digitizer with 500 kSPS and 16 bits resolution, a 8-channel 14 bits fast digitizer with 10 nsec resolution and the oscilloscopes for fast data capture with nanosecond resolution. Different tools have their features and limitations. Many trip events have been identified during the last several years and contributed to improve reliability of TLS.

BEAM TRIP DIAGNOSTIC TOOLS

The beam trip related signals include trip trigger, beam current, superconducting RF system signals and interlock, and kicker waveforms, quench detector and interlock output of superconducting insertion devices, beam position. Time resolutions of these signals are spanned from nanosecond to second - near nigh order of magnitude. Beam related events require higher time resolution than trips caused by the supporting systems' parameters out of some threshold (temperature, flow rate, liquid level and etc.).

A complete beam trip diagnostics consists of the data recorders and the slow archiver. This system possesses time resolution from nanosecond to second range as shown in Fig. 1. Existing available beam trip event diagnostic tools include control system archivers, oscilloscopes, Vision XP data recorders [1], D-tAcq196 cPCI based digitizers [2], V1724 VME based digitizers [3] and post-mortem data buffers inside the BPM electronic - Libera Brilliance [4].

The control system of TLS supports a 10 Hz logger with one week lifetime and a 10 seconds resolution archiver for permanent storage. However, it is unable to clarify the reason for fast beam trip. The Vision XP is data recorder with rich functionalities. Its 10 μsec time resolution satisfies minimum requirement to clarify reasons of beam trip by analysis of the captured data. Oscilloscopes are used to observe fast events up to nanosecond resolution, such as pulse magnets waveforms, beam signals, RF related fast signals. Segmented capture is very useful to capture fast signal with longer record time. The D-tAcq196 is a cPCI form factor 16 bits digitizer equipped with 96 channels and up to 500 kSPS simultaneous sampling. It can be applied to acquire low speed signal data of the diagnostics system. Its functional block diagram of the proposed system is shown in Fig. 2. The V1724 8 channel digitizer VME module, which has a maximum 100 MS/sec sampling rate with 14 bit ADC, is also considered. It can daisy chained up to 8 modules and connect to PC/Linux computer via optical link as shown in Fig.3. It can meet high time resolution and low rate data requirement by the aids of decimation and gating functionality. Precision timestamp (~nsec) is supported for synchronizing and capturing various signals from different modules. Data acquisition and analysis can be done at the control console easily. The post-mortem buffer inside the Libera Brilliance is used to capture turn-by-turn beam intensity, position and phase up to 256 K samples when beam trip trigger happened. This buffer can be dump for further analysis.

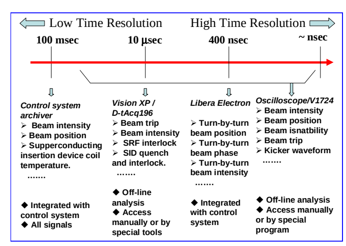

Figure 1: Available beam trip event diagnostic tools.

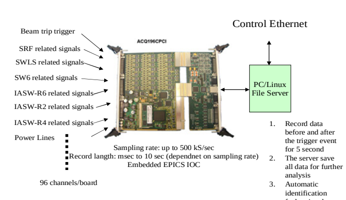

Figure 2: The cPCI based high density digitizer.

To synchronize the data captured by various devices, a beam trip detector was implemented to generate a trigger for all trip diagnostics devices. The functional block diagram of the beam trip detector is shown as Fig. 4. The beam trip condition is defined when beam intensity is dropped more than 30% within 500 turns. This condition

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can be revised if necessary. The beam intensity signal is derived from the sum signal of four buttons from a beam position monitor.

Three superconducting insertion device SWLS, SW6 and IASW-R6 have been installed. Two superconducting wiggler IASW6 will be installed soon. The quench detector and interlock logic are developed for all superconducting IDs to protect the coil from damage. The quench detector output can also be used to trigger the post-mortem data capture process.

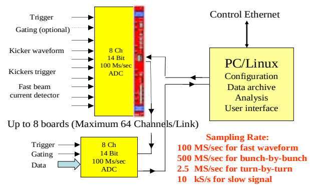


Figure 3: The VME based fast digitizer.

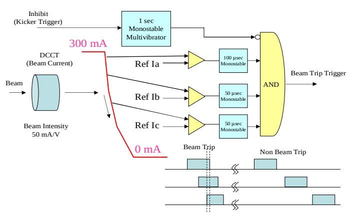


Figure 4: The beam trip detector.

SOME TRIP SCENARIOS

The beam trip diagnostic tools are applied to clarify the resulting causes of these trips and essential to obtain detailed information; according to analysis of this information, system reliability is improved. Therefore, a diagnostic system that can elucidate the reason for a trip will be established and a useful solution is being sought. Some real scenarios are summarized to demonstrate the usage of these diagnostic tools.

Superconducting Insertion Device Quench

The archiver data shows something wrong with the SWLS of which the problem cannot be verified due to lower 10 Hz time resolution. But by the data captured by Vision XP as shown in Fig. 5, we can easily identify the problem caused from the power supply itself rather than real quench of the coil, because coil current drops to zero first. Coil current of SWLS is dropped to zero suddenly while coil voltage fluctuates after main power trip that activates the quench detector. After check of the main power supply, it was found that the actual problem is the firmware bug of the controller. After upgrade of the power supply control firmware, this error is cleared.

In the Fig. 6, it is obvious that the beam trip was caused from beam loss induced quench of the SW6 and the IASW-R6 from data of the Vision XP. Fig 6(a) shows that beam loss induced by SW6 quench causes the SW6 trip. The beam current continues drop, and about 43 second later, the beam loss induced IASW-R6 quench and SRF interlock active trips beam during injection period as shown in Fig. 6(b).

The data captured by D-tAcq196 is shown in Fig. 7. The trip that resulted from the power supply itself rather than real quench of the coil is easily distinguished because coil current drops to zero first.

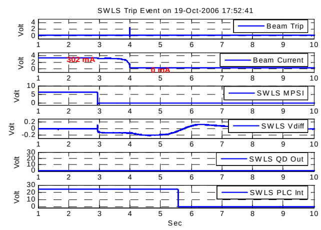
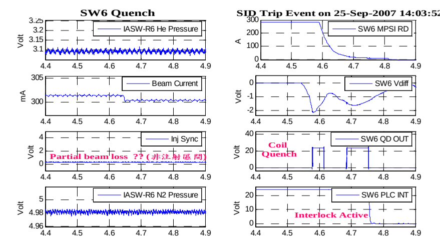
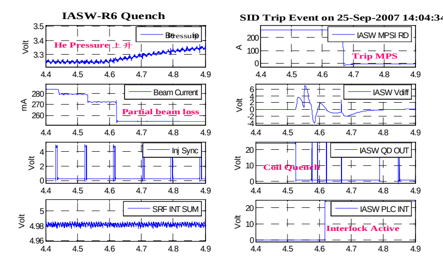


Figure 5: The beam trip caused by SWLS main power supply failed



(a) The SW6 quench.



(b) The quench of the IASW-R6.

Figure 6: The beam loss induced quench of the superconducting insertion device, (a) Quench of the SW6. (b) Trip of the IASW-R6.

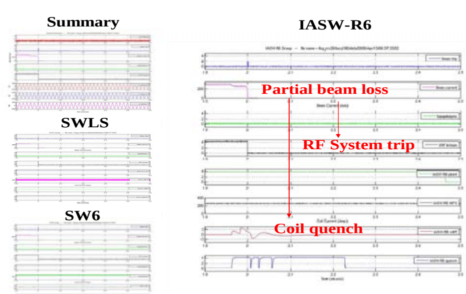
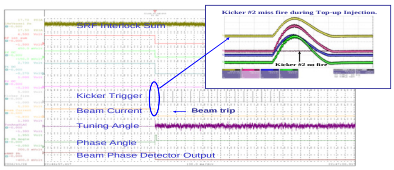


Figure 7: The D-tAcq196 for superconducting insertion device quench diagnostic. The partial beam loss induced coil quench of the IASW-R6 and RF system trip.

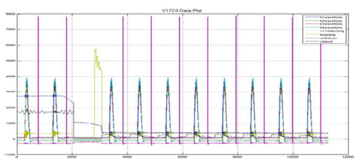
Kicker Misfired

Missed fired, spontaneous fired without trigger, and large timing jitter or drift were happened occasionally of the injection kickers. When these happened during top-up operation, it will cause unintentional beam loss, the SRF system trip and superconducting insertion devices trip. Figure 8(a) shows miss fire of one of a kicker pulse in top-up operation. This event also caused the sequence SRF system trip.

During top-up injection period, the V1724 high speed digitizer can always monitor per shot injection kicker waveform, the diagnostic system can automatically capture and store the kicker waveform, kicker trigger, beam current, SRF interlock sum and beam trip signal when beam trip event active. The beam trip caused by injection kicker waveform mismatch when the kicker #1 timing shift -150 nsec is shown in Fig. 8(b).



(a) The beam trip caused by kicker misfired.

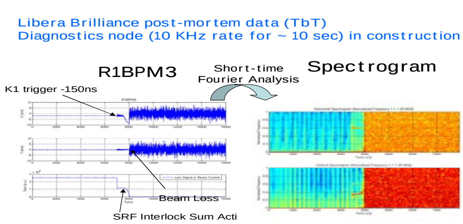


(b) The beam trip caused by kicker mismatched.

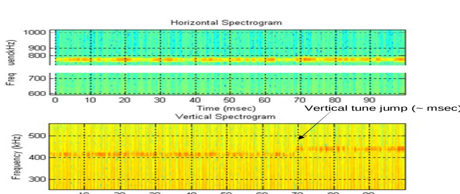
Figure 8: The beam trip caused by kicker misfired or mismatched. (a) The beam trip caused by kicker misfired. (b) The beam trip caused by kicker over mismatched.

Beam Position Monitor

The Libera Brilliance is equipped with up to 256K post-mortem buffer for the turn-by-turn beam position data. The post-mortem data capture is trigger by beam trip, superconducting insertion devices quench and RF system trip signal. The BPM post-mortem beam position can be utilized for analysis of various events. Fourier analysis of the post-mortem beam position data can be one method to analyze the tune change due to various trigger events also. Typical post-mortem data and spectrogram of the post-mortem data is shown in Fig. 9 for a BPM reading.



(a) The beam position and its spectrogram in beam trip.



(b) The spectrogram during IASW-R6 quench.

Figure 9: Libera Brilliance post-mortem data for the beam position and tune measurement. (a) The BPM post-mortem data for the large kicker jitter. (b) The BPM post-mortem data for IASW-R6 trip.

Linac Klystron Stand Arcing Diagnostic

Arcing inside the oil tank of the klystron stand in the linear accelerator is the precursor of the insulation breakdown. Arcing of a few cycles will not cause trip of the klystron modulator, but arcing frequency will increase gradually before the system breakdown. Oscilloscopes working in segmented trigger are used to capture such kind of event as shown in Fig. 10. This observation helps to clarify the problem quickly. Of course, a simple pin-hole CCD camera is also very useful to directly observe the light due to arcing.

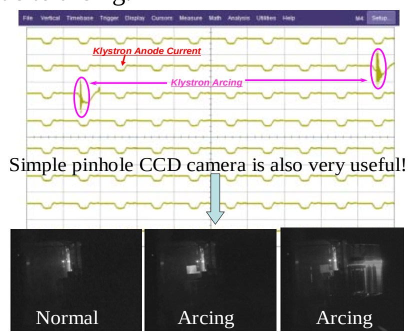


Figure 10: Oscilloscope working in segmented trigger mode to capture arcing problem of the klystron modulator in the linear accelerator system.

SUMMARY

Trip event analysis can be aids of learning appropriate action to improve sub-system, to avoid dangerous operation conditions, and consequently improve system reliability. Several diagnostics tools are available for the TLS. Some devices are operated in proprietary environment. There will be more manpower involved to collect the trip information. Inhomogeneous operation environment makes it difficult to put all necessary data together. To simplify the system and provide more transparency environment, it is planned to simplify the hardware type and to develop software to collect the data and store at the dedicated server automatically. The trigger for the data capture comprises beam trip, superconducting insertion devices quench trip, RF system interlock sum, and etc. Integration of all software tools is ongoing. Automatic tools will be developed to extract the event and the result can be saved into the log file of the machine operation for further usage. It is expected the reliability of the TLS can be improved further by the aids of these tools.

REFERENCES

[1] Vision XP: http://www.lds-group.com.
[2] cPCI digitizer: http://www.d-tacq.com.
[3] VME digitizer: http://www.caen.it/.
[4] Libera Brilliance: http://www.i-tech.si.